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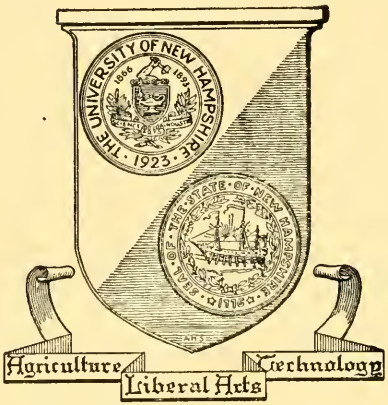

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Preharvest Apple Drop

With Special Reference to

McIntosh

By L. P. LATIMER

AGRICULTURAL EXPERIMENT STATION
UNIVERSITY OF NEW HAMPSHIRE
DURHAM, N. H.

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By L. P. Latimer, Assistant Horticulturist

McINTOSH APPLE TREES have the bad habit of frequently dropping a considerable proportion of their fruit before the desired amount of red color has developed. Red color is an important requirement for "Fancy" and "A" grade McIntosh. Under-colored fruit, although sound and free from blemish, must be sold as "B" grade.

MacDaniels[12] found that dropping was preceded by the formation of an abscission layer across the pedicel of the fruit. Dickerson[4], MacDaniels[12], and Southwick[15] have suggested that a reduced nitrogen supply in the soil results in fewer drops and better color than when nitrogen is abundant.

Spot-picking has been suggested as a means of preventing serious loss by the pre-harvest drop. This method of harvesting apples, however, involves greater expense. Therefore, there has long been a desire for a method of preventing dropping before all the fruit has developed sufficient color for commercial purposes. For this reason, in 1938, an investigation was begun to determine the factor, or factors, responsible for the pre-harvest drop. It should be noted particularly that this work was begun before Gardner *et. al.*[6] had reported the beneficial effect of growth-promoting substances in reducing the pre-harvest drop of certain apple varieties.

For several years previous to the initiation of this project, records were kept on the proportion of dropped fruit in the Experiment Station orchard at Durham, New Hampshire. Data obtained from 1932 to 1937 on the per cent drop of fruit from 50 eighteen-year-old trees located in the section of the orchard known as the BFP block were subjected to analysis of variance. The results showed that certain trees dropped a significantly greater per cent of fruit annually than others in the same block. There seemed to be a tendency for the lighter-dropping trees to be more or less grouped together. The same is also true for heavy-dropping trees.

It was thought first that differences in the rate of dropping might have been caused by rootstock differences. If this were the case, heavy-and light-dropping trees could hardly be expected to be segregated into groups as these were. Therefore, it was assumed as more probable that soil differences, either physical or chemical, might be the cause of the differences in amount of fruit-dropping in the different areas of the BFP block.

EFFECT OF SOIL

The eight trees in the block identified as BFP which dropped the greatest and the eight which dropped the least percentage of fruit annually were used in this investigation. The difference in per cent

Table 1. Per Cent Drops for McIntosh Trees Selected for Soil Studies

Tree No.	Year 1932	1933	1934	1935	1936	1937	Average
8	0.0	9.2	7.7	4.4	9.9	33.9	10.8
14	8.0	13.6	7.8	21.9	6.2	13.0	11.7
18	0.0	16.5	7.9	16.8	0	11.9	8.8
44	7.1	27.0	6.2	8.1	8.3	16.6	12.2
62	4.0	12.0	3.8	16.9	11.0	11.1	9.8
64	7.8	19.2	7.4	23.1	13.0	9.6	13.3
68	4.5	14.3	7.6	10.0	8.3	9.0	8.9
70	7.4	20.9	7.5	9.4	14.4	5.9	10.9
Average	5.5	16.6	7.0	13.8	8.9	13.9	10.8
10	11.2	36.0	32.2	21.0	9.5	80.0	31.7
12	28.6	37.4	5.5	12.8	32.4	47.3	27.3
56	10.0	55.4	9.0	37.8	16.2	48.5	29.5
58	0	55.2	10.4	26.9	14.9	47.5	25.3
88	10.7	42.5	9.8	57.1	26.6	20.9	27.9
90	14.1	41.3	12.4	57.8	28.1	33.1	31.1
94	12.5	32.4	11.5	27.2	31.7	44.7	26.7
116	10.3	49.0	15.6	34.3	35.2	34.8	29.9
Average	13.9	43.6	13.3	34.4	24.3	44.6	28.7

drop between the two lots from 1932 to 1937 was statistically significant (Table 1), yet there was no significant difference between trees in these groups in total yield over the same period (Table 2).

The soil of this block has been classified as Charlton Loam. The depth of tree-root penetration is affected by the hard, platy till layer which underlies the entire block. In some places this layer comes to within a foot of the soil surface, in others it is five feet below the

Table 2. Yield Lbs. of Fruit of McIntosh Trees Selected for Soil Studies

Year	1932	1933	1934	1935	1936	1937	Total
Tree No.							
8	1	190	23	229	55	18	516
14	68	783	201	538	126	491	2207
18	4	620	56	499	31	432	1642
44	28	586	130	430	155	343	1672
62	110	840	45	777	195	736	2703
64	116	1001	312	770	133	679	3011
68	89	862	13	657	327	233	2181
70	74	614	64	417	336	322	1827
Total	490	5496	844	4317	1358	3254	15759
Tree No.							
10	134	545	31	315	98	323	1446
12	4	307	129	226	132	148	946
56	10	798	73	535	47	635	2098
58	0	529	141	428	105	516	1719
88	56	820	37	548	44	339	1844
90	42	754	51	464	64	218	1593
94	12	743	122	346	226	133	1582
16	8	851	85	434	56	585	2019
Total	266	5347	669	3296	772	2897	13247

surface. Furthermore, there is considerable variation in the thickness and distribution of the different soil zones located above the till layer. It was thought that these factors might cause differences in the size and distribution of the root system of different trees; also in the ability of different trees to obtain water and nutrients, which, in turn, might have an influence on the ability of the fruit to remain attached to the tree. For these reasons soil profile studies were made to determine the difference, if any, in the number and size of roots, and of the root distribution of these trees in the different soil zones; also to observe any difference in the distribution and extent of the several soil layers and the possible relation to root distribution and tree performance.

In June, 1938, excavations 10 feet long and 2 feet wide were made at a distance of eight feet from the north side of the trunk of each tree. The depth of each excavation was determined by the underlying hard till layer, and digging was stopped after penetrating several inches into this layer. Because of the lack of uniformity in the depth

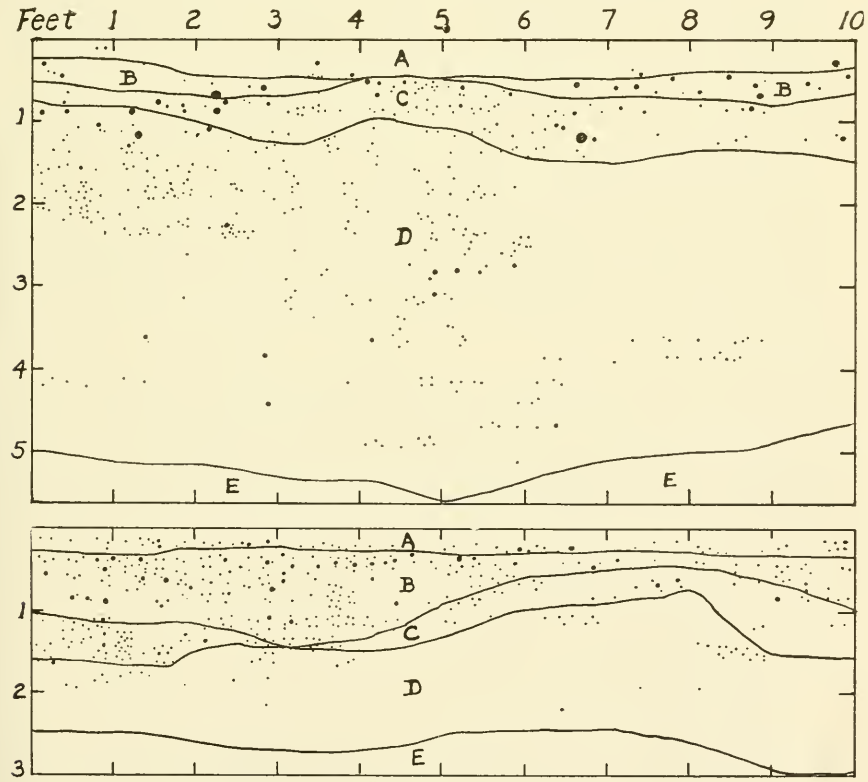

Fig. 1. Distribution of Roots and Profile Zones under tree No. 18 (upper) and tree No. 8 (lower).

A, B, C, D, E indicate soil zones as described in the text. Relative size of roots is indicated by dots and circles. Small dots represent roots 2 mm. or less in diameter. Both charts represent light-dropping trees.

of the upper boundary of the till layer, the trenches were necessarily of different depths. Charts were made of the treeward side of each excavation, indicating thereon the contours of the different soil zones and the position and diameter of all exposed roots which were severed during the excavation. The actual diameter of each root 2 mm. or over, was so designated on the charts, the smaller roots as "less than 2 mm." The profile charts for excavation under two of the trees are shown in Fig. 1.

A. Physical

The soil layers, or zones, encountered are designated by letter and are described as follows:

Zone A. Top soil, dark brown loam ranging in depth from 2.9 to 8.5 inches and under one tree 14.1 inches.

Zone B. Brown, mellow loam down to an average depth of 9 inches, ranging from 5.9 to 15.3 inches below the soil surface.

Zone C. Yellowish brown to rusty yellow-brown sandy loam of crumb structure, down to an average depth of 16.5 inches, ranging from 11.1 to 29.0 inches below the surface.

Zone D. Slightly olive-yellow material of crumb structure, with many small and some large stones, also coarse and fine gravel, to an average depth of 43.6 inches, ranging from 18.1 to 61.2 inches below the soil surface.

Zone E. Olive to grayish green, hard platy till; the top of this layer averaged 31.6 inches below the soil surface, ranging from 11.9 to 61.2 inches; the thicknes sof this layer was not determined.

Occasional pockets of fine gray sand were encountered in some of the excavations.

The A, C, and E layers were universally present in the block; the stony D layer was absent under 8 trees located on the lower slope of the orchard; the mellow B layer was absent under 5 of the trees. Differences in drop cannot be accounted for by differences in zone thickness (Table 3), and there was apparently no correlation between the absence of any of these layers and the amount of fruit dropping.

Table 3. Average Thickness Soil Zones (Inches)

Series	Soil Zone A	B	C	D
Light-Dropping Trees	5.7	4.4	7.0	25.8
Heavy-Dropping Trees	5.4	4.8	8.4	30.1

Since water and nutrients are absorbed principally through the root hairs, the greatest interest lay in a study of roots less than 2 mm. in diameter. For each tree a summary of the total number of roots less than 2 mm. in diameter exposed by the excavations is presented

Table 4. Number of Roots Less than 2 mm. in Diameter Exposed by Excavations

Light-Dropping Trees	Soil Zone A	B	C	D	E	SC	Total
No. 8	43	199	83	45	0	*	370
14	4	5	54	48	0	*	111
18	6	10	84	278	0	*	378
44	17	2	59	114	15	*	207
62	16	*	91	*	45	*	152
64	11	*	61	*	7	*	79
68	42	70	3	*	0	56	171
70	33	*	44	*	0	29	106
Total							1574
Heavy-Dropping Trees							
No. 10	50	98	64	205	0	*	417
12	21	49	62	282	0	*	414
56	1	38	49	*	1	*	89
58	11	45	17	210	0	*	283
88	2	18	43	*	6	*	69
90	7	*	37	*	10	*	54
94	0	35	51	*	17	*	103
116	54	*	171	51	0	*	276
Total							1705

in Table 4. The total number of roots less than 2 mm. in diameter ranged from 54 under tree #90 to 417 under tree #10, yet both of these trees were heavy droppers. On the other hand, there were 378 of these small roots under tree #18 while only 79 were encountered under tree #64, both trees being light-droppers. The difference between total number of such roots under heavy-and light-dropping trees was not statistically significant.

The percentage of the total number of small roots located in each soil zone is shown in Table 5. Although variation between trees was large, it is evident that two-thirds of the small roots were located in the combined C and D zones, and approximately one-fourth in the combined A and B layers. Yet it must be remembered that the combined C and D layers occupy a much larger volume of soil than the A and B zones. Few small roots penetrated the E layer except where this layer was closest to the soil surface (trees 44, 62, 64, 88, 90, 94). Light-dropping-and heavy-dropping trees had the same percentage of roots located in like soil zones; hence, differences in the location and thickness of the soil zones apparently were not a factor in causing differential dropping.

Table 5. Per Cent of Total Number of Roots Less than 2 mm. Diameter in Different Soil Zones (Average Per Tree)

..	Zone A + B	C + D + SC	E
Light-Dropping Trees	26	68	6
Heavy-Dropping Trees	27	68	5

There was no difference between heavy-and light-dropping trees in density of population of small roots in any given soil zone. In both cases the greatest density of population of small roots occurred in the B and C layers, the least in the A layer. The latter condition may possibly be due to the fact that few small roots were encountered in the top 3 inches of soil because of frequent injury by the cultivator discs.

Fig. 2 shows that there were the same average number of small roots in the top 9 inches of soil under both heavy-and light-dropping trees. Between the 9-and 21-inch level there were more small roots under the light-dropping trees. Below 21 inches the greatest number of roots were found under the heavy dropping trees without relation to zone. Thus, conditions seemed less favorable for the development of small roots at the deeper levels under light-dropping than under heavy-dropping trees. Whether the greater number of small roots below 21 inches enabled the heavier-dropping trees to obtain more water and nitrogen in not known. That there were exceptions to the general rule is indicated by the fact that trees #88 and #90 located in topsoil only one foot deep were heavy-droppers while tree #70, a light-dropper, was growing in soil only 14 inches deep. Dickson[4], MacDaniels[12], and Southwick[15] concluded that increased nitrogen supply results in heavier drop. It is possible that more deeply rooting trees were able to obtain a greater total amount of nitrogen, especially in dry weather, thereby being a factor contributing to heavier drop.

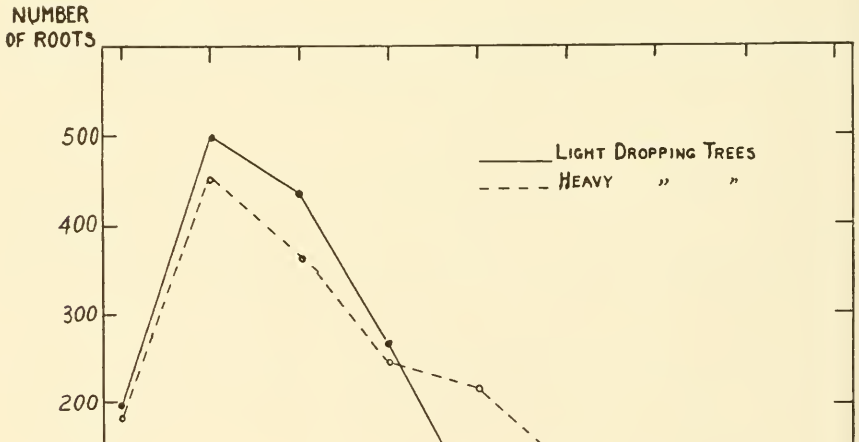

Fig. 2. Number of roots 2 mm. or less in diameter located at different depths below the soil surface.

B. Chemical

Since differences in root distribution due to differences in soil profile were not found definitely to cause the difference in behavior of these trees with respect to dropping fruit, the probability of differences in soil pH and content of mineral elements was investigated.

Acidity. Although the soil tended generally to be slightly more acid under heavy-dropping trees, the differences do not seem large enough to account for observed differences in drop (Table 6). It is of interest to note that in the A and B zones the pH of the soil under trees 58 and 88 was only 3.9 to 4.0.

Table 6. pH of Soil

Tree	Class	Zone A	B	C	D	E
8	L	4.72	4.94	5.51	5.53	5.82
14	L	4.86	5.08	5.08	5.34	5.61
18	L	5.20	4.56	4.84	5.57	5.86
44	L	5.83	5.78	5.66	5.39	5.18
62	L	4.20	*	5.05	*	5.34
64	L	4.91	*	4.71	*	5.22
68	L	4.70	5.02	5.24	*	5.44
70	L	4.18	*	4.59	*	5.33
10	H	4.60	5.49	4.43	4.66	5.38
12	H	4.72	4.86	4.57	5.04	6.37
56	H	4.42	4.16	4.28	*	4.80
58	H	3.88	3.92	4.34	5.09	5.29
88	H	4.06	3.93	4.08	*	4.92
90	H	5.50	*	5.12	*	5.04
94	H	4.12	4.46	4.69	*	5.26
116	H	4.75	*	5.22	5.29	5.42

L Light-dropping trees H Heavy-dropping trees * Zones not present

Chemical Elements. The available elements determined were: nitrate nitrogen, ammonia nitrogen, phosphorus, aluminum, magnesium, potassium, and calcium. Table 7 shows that available nitrate nitrogen was highest in the A zone and generally lacking in the D and E zones. Ammonia nitrogen, on the other hand, was more evenly distributed throughout the soil. The very slight difference in nitrogen content of the soil under light-and heavy-dropping trees did not seem sufficient to account for the difference in apple drop.

Table 7. Amount of Available Nutrients Present in Soil

Class	Nitrate Nitrogen L'	Nitrate Nitrogen H'	Ammonia Nitrogen L'	Ammonia Nitrogen H'	Phosphorus L'	Phosphorus H'	Aluminum L'	Aluminum H'	Magnesium L'	Magnesium H'	Potassium L'	Potassium H'	Calcium L'	Calcium H'
ver														
A	LM	LM	LM	LM	L	L	H	H	ExL	ExL	ExL	ExL	ExL	ExL
B	VL	L	LM	VL	M	L	H	H	ExL	ExL	T	T	O	O
C	VL	VL	L	L	LM	L	H	H	ExL	ExL	T	T	T	O
D	T	T	VL	VL	LM	LM	M	M	ExL	ExL	T	T	O	O
E	O	T	L	L	LM	LM	MH	M	VL	VL	T	ExL	T	T

— None
— Trace
L — Extremely low
— Very low
L — Low
LM — Low-to-medium
M — Medium
MH — Medium-to-high
H — High
L' — Low-dropping trees
H' — High-dropping trees

Available phosphorus was more concentrated in the D and E zones and was slightly higher in the B and C layers under the light-dropping trees. Magnesium, although available in small amount, tended to be more concentrated in the E layer. Available potassium was also present in very small amount. Aluminum and calcium tended to be more concentrated in the A zone. This soil was high in soluble aluminum but there was less calcium available than any other element. Except for phosphorus the differences in available amounts of each element beneath heavy- and light-dropping trees were not in any case large enough to account for differences in drop.

Humus was low in the A zone and very low in the other zones*.

RELATION OF YIELD TO DROP

Southwick[16] studied the relation between yield and per cent drop with McIntosh, and from the values obtained for coefficients of determination concluded that not more than 15 to 28 per cent of the variance in drop could be attributed to the effect of yield. Furthermore, of 6 plots only 3 showed a significant positive correlation between yield and per cent drop. Apparently his calculations were based on the average yield and drop from 1927 to 1937.

Correlation coefficients, determined for the relation between yield and per cent drops in several of the New Hampshire Station blocks, are presented in Table 8. The data confirm the observations of Southwick[16] in that there is indicated a variable association between yield and per cent drop. None of the correlations are large. Southwick[16] also found that dropping increased with increase in yield. Dickson[4], working with McIntosh, found that the per cent of drop increased with increasing yield due to improved cultural or growth conditions, but not when increased yield was due to on-year cropping. In the writer's experience this correlation was not consistent with relation to on-year cropping.

For McIntosh and Baldwin correlations between yield and per cent drop large enough to be significant are positive; for Northern Spy, Delicious, and Starking they are negative. This simply means that in some years the heavier-yielding McIntosh trees dropped a larger percentage of their fruit than did lighter-yielding trees. With Northern Spy, the reverse is true; heavier-yielding trees dropped a smaller percentage of their fruit.

In considering correlation between drop and yield one must not confuse per cent drop with the actual weight of dropped fruit. In fact, the correlation between per cent drops and yield of Northern Spy in the BFP block in 1935 was —.407, whereas the correlation between weight of drops and yield was .760, a change from a negative to a positive correlation. Although the percentage of drops was less with the heavier-yielding trees, they actually dropped a greater amount of fruit than the lighter-yielding trees.

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*Chemical determinations were made by quick test methods in the Agricultural Chemistry Department by G. P. Percival.

Table 8. Correlation Between Yield and Per Cent Drop

Variety	Block	Year	r	Number of trees	Average Yield (lbs.)
McIntosh	26	1935	—.044	31	154.5
		1936	.078	29	153.3
		1937	.301	33	166.8
		1938	.346*	35	156.2
		1939	.143	38	379.1
		1940	.494**	37	279.2
		1941	.338*	35	566.4
McIntosh	BFP	1932	—.066	49	47.4
		1933	.226	58	702.0
		1934	—.038	51	103.2
		1935	.337**	60	480.3
		1936	—.020	59	136.7
		1937	—.100	61	404.8
McIntosh	BF	1935	.380**	64	308.1
		1936	.000	68	119.3
		1937	.355**	71	538.7
		1938	.271*	71	119.9
		1939	.442**	87	461.3
		1940	.383**	88	490.0
		1941	—.067	90	491.3
Northern Spy	BFP	1935	—.407**	60	416.6
		1936	—.451**	57	398.0
		1937	—.192	60	485.4
		1938	—.405**	50	199.7
		1939	.101	61	820.1
		1940	—.516**	52	192.8
		1941	—.501**	59	488.6
Starking	26	1938	—.607**	25	73.9
		1939	.000	31	180.9
		1940	.000	30	197.9
		1941	—.509*	14	70.2
Delicious	BF	1935	.090	40	——
		1936	—.083	36	——
		1937	.122	40	——
		1938	—.499**	39	——
		1939	—.119	43	——
		1940	.080	38	——
		1941	—.241	38	——
Baldwin	26	1940	.666**	42	210.0

* Significant ** Highly Significant

The writer realizes that the correlation coefficient is of value only in indicating whether a change in the value of one factor is accompanied by a change in another factor, but cannot be used like regression to show the magnitude of the change, since, as stated by Snedecor[14], "the correlation is the regression freed of differences in units and in magnitude of variation."

The value of the correlation coefficient does not give information on the real effect of yield on drop unless the magnitude of change in per cent drop with change in yield is also taken into consideration. Likewise, the correlation coefficient for the relation between weight

of drops and yield does not give us a picture of the actual amount of drop unless the magnitude or the actual change in weight of drops with change in yield is also known.

Fig. 3A shows the regression line for the relation between per cent drop and yield of Northern Spy in the BFP block in 1935. The regression line predicts the average decrease in per cent drops with increased yield per tree. Thus, with a yield of 200 pounds per tree, the drop averaged 8 per cent, while with a yield of 1000 pounds the drop averaged 3 per cent; yet a tree yielding 1000 pounds of fruit dropped twice as much fruit by weight as one yielding 200 pounds. This is shown directly by calculating the regression equation on the basis of weight of dropped fruit (Fig. 3B).

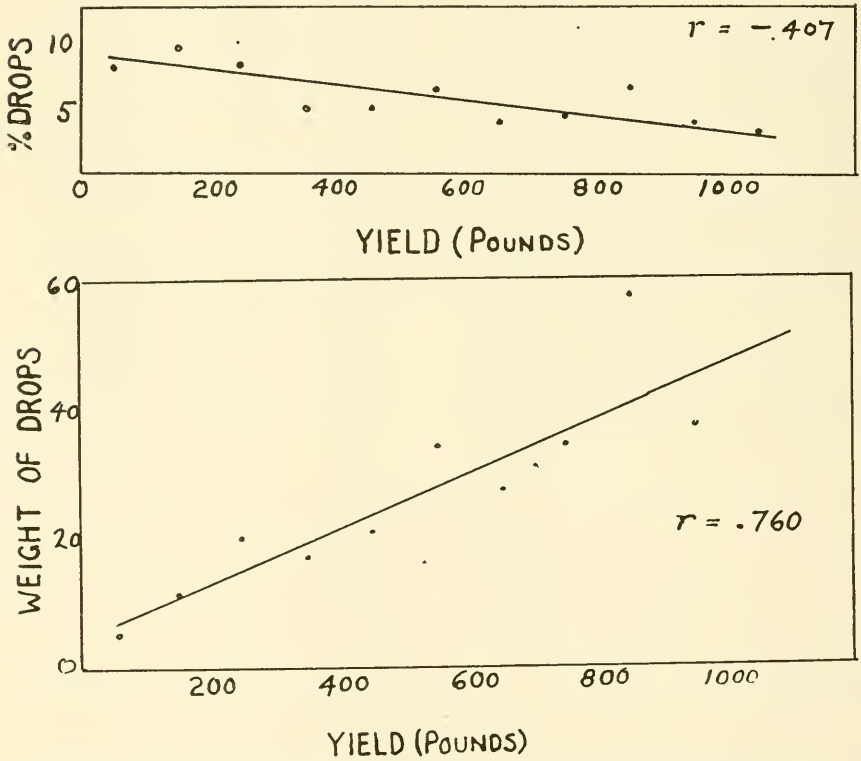

Fig. 3. A. (Upper) Regression of per cent drops on yield; B. (Lower) Regression of weight of drops on yield. Northern Spy, 1935, B. F. P. block, 60 trees.

With McIntosh in the BFP block, covering the period from 1932 to 1937, there was a correlation coefficient of —.099 between per cent drop and total yield, and .563 between weight of drops and yield. From the regression equation, trees yielding 1000 pounds dropped 125 pounds of fruit and those yielding 3000 pounds dropped 440 pounds of fruit during the 6-year period. Here there is no correlation be-

tween per cent drop and yield; therefore we cannot give an estimate of the number of bushels dropped unless regression for weight is known. A lack of correlation or a correlation coefficient of zero between per cent drops and yield could mean either that the per cent drop was the same for all trees or else that it was high for both heavy-and light-yielding trees and lower for intermediate yielders, or vice versa. This is further evidence of the greater value of actual weight rather than a percentage relationship in evaluating the change in amount of drops with change in tree yield.

Likewise, with McIntosh located in the part of the orchard known as the BF block, there was no correlation between per cent drop and yield from 1935 to 1941, yet there was a correlation of .953 between weight of drops and yield. This is nearly a perfect correlation and, estimated from the regression equation, McIntosh trees bearing 1000 pounds of fruit would drop 360 pounds and those yielding 3000 pounds would drop 869 pounds of fruit. On this basis it may be seen that each tree dropped the equal of one year's crop during a period of 4 years. From the grower's point of view, such data, obtained over a long period of time, would be of considerable significance.

The correlation between per cent drops and yield on different harvest dates for individual trees and in individual years is shown in Table 9. The correlations in general are higher than those based on the total crop harvested during the season. There is less variability in the correlation between per cent drops and yield on the later-picking dates. There is also a high correlation between per cent drop and yield on the trees harvested on the later dates. This indicates that heavy yield becomes a more important factor in dropping as the season advances, that it is highly important to consider the maturity of the fruit and tree in studying the relation of yield drop, and that the individuality of different trees must not be overlooked.

Table 9. Correlation Between Yield and Percentage Drop on Different Harvest Dates

Year	Harvest Date	McIntosh r	No. of Trees
1937	9/22	.566**	22
1937	9/23	.692**	23
1939	9/13 - 14	—.073	20
1939	9/22, 23, 25	.943**	20
1940	9/23	.253	15
1940	9/26	.591*	14

* Significant ** Highly Significant

It should be understood, therefore, that with increased yield there would be more dropped fruit to handle, and increased expense in handling the crop. Therefore, the results of these calculations are not to be interpreted as an urge to disregard drop when there is no correlation or when there is a negative one between per cent drop and yield.

When yield and weight of drops are considered for the entire period 1935 to 1941, there was a very high positive correlation with McIntosh, Delicious, Gravenstein, Starking, and Baldwin, the lowest being with Spy (Table 10). It is certain that differences in correlation coefficients within varieties for different years are due in part to differences in seasonal effects and discrepancies with relation to harvest dates. It has been the practice at the horticultural farm to pick McIntosh over a longer period than other varieties, the lighter-yielding trees and the higher-colored fruit usually being harvested first. This was true in years of medium-to-heavy yield. Also, except in 1936 and 1941, the per cent drop increased as picking was delayed, but not at the same rate in different years; nor was this difference correlated with size of the crop. Climate and other factors must influence the amount of drop to account for these differences.

Table 10. Correlation Between Yield and Weight of Drops

Variety	Block	Years	r	No. of Trees
McIntosh	BFP	1932-41	.563**	47
McIntosh	BF	1935-41	.953**	70
Northern Spy	BF	1935-41	.925**	11
Northern Spy	BFP	1935-41	.477**	60
Baldwin	'26	1935-41	.873**	40
Delicious	BF	1935-41	.893**	11
Gravenstein	BF	1935-41	.968**	12
Starking	'26	1935-41	.921**	32

* Significant ** Highly Significant

Recently Welker and Wynd[19] have emphasized that "groups of biological data obtained under different conditions cannot be pooled in an effort to increase the significance of statistical correlations by increasing the number of pairs of variates." Also that "factors of unknown nature may falsely exaggerate or diminish the numerical magnitude of the observed correlation coefficient." Furthermore, "these factors may even change the algebraic sigh of correlations obtained from the pooled data."

The writer has presented the preceding section on correlation between yield and drops especially to bring out the fallacy of using correlation data in interpreting any effect of yield on drops without also having some knowledge of the other factors that may be affecting the relation but are not revealed by the correlation coefficient. Such factors as soil moisture, nutrient supply, spray materials, weather conditions etc., vary considerably from year to year. This causes one to question the value of correlation coefficients obtained by using pooled data obtained over a period of years. Similarly, in any given year the picking date has a profound effect on the correlation between drops and yield. Pooling the data from a number of trees in any given year is also under suspicion since, even with a given variety, fruit on different trees may not be at the same stage of maturity on the same harvest date. Before using correlation data to substantiate conclusions on the cause of any relationship one should, therefore, be certain that all factors which could possibly influence the relation are

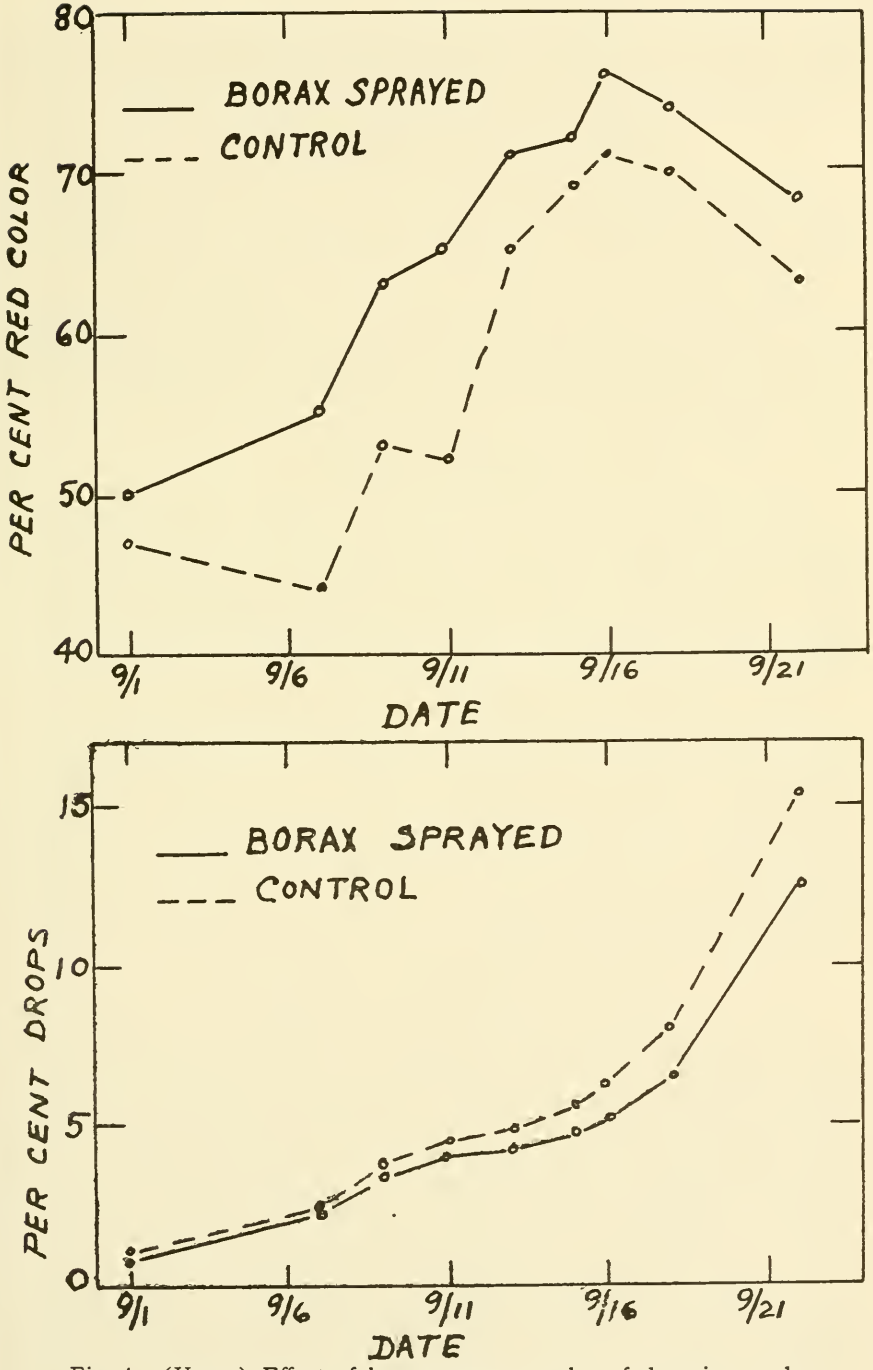

Fig. 4. (Upper) Effect of borax spray on color of dropping apples. (Lower) Effect of borax spray on per cent drops.

known and that pooled data are obtained from a homogenous population. In general the total weight of drops over a series of years will give the most accurate picture for the purpose of comparison.

EFFECT OF THINNING FRUIT

In 1939, just after the June drop, 16 trees setting a full crop were paired according to tree diameter and size of top. One of each pair was thinned so that fruits averaged 5 inches apart, the others were left unthinned.

On the basis of total drops before harvest, some thinned trees dropped about twice as great a proportion of their crop as controls of the same pairs. Of the remainder, the unthinned trees dropped the greater percentage of fruit so that the average difference in per cent of drops between thinned and unthinned trees was not statistically significant.

BORAX SPRAYS

Sixteen other trees were selected in the same way as for the thinning test, but none of these was thinned. One of each pair was sprayed with 2 pounds of borax per 100 gallons of water on July 7 and again on July 27, 1939. Fig. 4 shows that apples held approximately 2 days longer to the trees which had been sprayed with borax than on the unsprayed trees, and by September 22 sprayed trees had dropped only three-fourths as much fruit as the controls.

Heinicke, *et. al.* (7) obtained a great reduction in the preharvest drop of McIntosh trees susceptible to cork by soil applications of borax in solution in July. The effect carried over to the following year's crop although there was no visible evidence of cork in the fruit in the second year. The borax applications had no effect on the fruit drop of trees previously free from cork. Batjer and Haller[2], on the other hand, found that when 20-year-old apple trees growing in a soil low in available boron were fertilized with 1 pound of borax, 3 weeks prior to bloom, the pre-harvest drop was greatly augmented, the per cent drop being nearly quadrupled.

EFFECT OF SEED NUMBER

Seed number influences drop and size of fruit. For all trees in both the thinning and borax tests there were, on the average, one to two more seeds in picked fruit than in drops from the same tree. Furthermore, thinned trees showed a definitely smaller difference in seed number between dropped apples and harvested fruit than did unthinned trees (Table 11). There was no significant difference in this respect between borax-sprayed and unsprayed trees (both unthinned). Apparently more fruits with a smaller number of seeds failed to drop from thinned than from unthinned trees where competition was greater. Thus spraying with borax did not overcome the competition between fruits of different seed number. Whatever effect borax may have had in causing more fruits to remain on the tree, few- and many-seeded apples were affected in like manner. It should be stated that these trees are located on a boron-poor soil and that

Table 11. Effect of Spraying with Borax and of Thinning on the Average Number of Seeds Per Fruit of McIntosh

Treatment	Picked Fruit	Drops	Difference
Not Sprayed with Borax			
Fruit Thinned	7.3	6.3	1.0*
Fruit not Thinned	8.1	6.3	1.8**
Difference	0.8	0	
Fruit not Thinned			
Sprayed with Borax	7.8	6.4	1.4**
Not Sprayed with Borax	7.8	6.2	1.6**
Difference	0	0.2	

* Significant ** Highly Significant

although these trees had never produced fruit with internal cork, there are trees in the same block which, in some years, have been rather severely affected.

In the earlier drops, seed number was slightly higher than in fruit that dropped just before the harvest date (Table 12). This is opposed to the findings of Southwick[16] that there was a moderate positive correlation between date of drop and seed content.

Table 12. Average Number of Seeds in McIntosh Drops on Different Dates

Date	Treatment				
	Fruit Thinned	Fruit not Thinned	Borax Spray	Unsprayed	Average
8/23	7.1	6.5	7.0	7.0	6.9
9/1	6.4	6.8	6.3	6.7	6.5
9/7	6.6	6.8	6.5	6.3	6.5
9/9	6.3	6.9	6.8	5.7	6.4
9/11	6.6	5.8	6.3	6.1	6.2
9/13	5.6	5.8	7.1	6.4	6.2
9/15	6.6	6.5	5.9	5.7	6.2
9/16	6.0	5.5	6.6	6.2	6.1
9/18	6.1	5.9	6.3	6.0	6.1
9/22	6.2	5.6	6.4	6.2	6.1
Picked Fruit 9/22, 23	7.4	8.1	7.8	7.8	7.8

The fruits from thinned trees were larger in both picked and dropped lots than those from non-thinned trees, but there was no difference in fruit size between borax-sprayed trees and unsprayed trees. In all treatments and controls, picked fruit averaged about 20 per cent larger than dropped fruit gathered at the same time. Difference in seed number affects the size of fruits on a given tree[11] but seed content differs between trees.

DROPPING AND FRUIT COLOR

Southwick[16] found in one block that well-colored fruit did not drop like pale, streaked fruit, but this condition was not consistent in another block. The writer could not discover any such correlation. Observations on 27 McIntosh trees in 1939 with relation to red

Table 13. Effect of Spraying with Borax and of Thinning on Per Cent of Red Color in McIntosh

Treatment	Picked Fruit	Drops	Difference
Not Sprayed with Borax			
Fruit Thinned	55	63	8**
Fruit not Thinned	56	64	8*
Difference	1	1	
Fruit not Thinned			
Sprayed with Borax	64	68	4**
Not Sprayed with Borax	56	62	6**
Difference	8*	6*	

* Significant ** Highly Significant

color of fruit and drops showed that on the same date the coefficient of correlation between color of fruit of different trees and percentage drops was —.027. Ten days before harvest date the dropped fruit possessed as much red color as fruit harvested from the tree. Dropped fruit from trees sprayed with borax possessed 10 per cent more color on the date of harvest than that from unsprayed trees, while fruit picked from the sprayed trees averaged 15 per cent more color than that picked from control trees (Table 13). The results, however, were not statistically significant, the average differences being due to the wide differences in color of fruit of a few individual trees.

HORMONE SPRAYS

Following the announcement by Gardner *et. al.*[6] that dropping of the apple could be lessened or possibly prevented with growth-promoting substances, some apple varieties in the block designated as "26" were sprayed in 1940 with ½ to 1 part per 100,000 naphthalene-acetic acid just as dropping commenced in the fall. The early varieties Melba, Early McIntosh, Gravenstein, and Milton definitely benefitted from the treatment. In fact, Melba fruit remained attached to the spurs until the flesh became so soft that it finally separated from the cores, leaving the latter attached to the tree indefinitely. On the other hand, fruit dropping of Cortland, McIntosh, and Spy was not retarded as a result of the treatment.

Since the air temperature was higher when the early varieties were sprayed, the failure of the hormone spray with late varieties was attributed to lower temperature at the time of spraying. In 1941, therefore, McIntosh trees in the BF block were sprayed with a commercial 'set' at the strength recommended by the manufacturer. Two rows were sprayed with the hormone in cold water, two rows with the hormone in warm water and two rows were left as a control. The results are presented in Table 14. Although application of the hormone in warm water had apparently reduced the pre-harvest drop while that in cold water had not, the differences were not large. Furthermore, the same trees showed significant differences in drop in previous years when none was sprayed with hormones. This leads

Table 14. Differences in Per Cent Drop Between McIntosh Sprayed with a Commercial 'Set' and Unsprayed Trees

Treatment	Number of Trees	Sprayed 1941	Unsprayed 1940	1939	1937	1936
Hormone in warm water	19					
Minus control	35	6.3*	10.8*	1.0	—6.0	2.9
Hormone in cold water	29					
Minus control	35	—1.6	—5.8	2.7	13.1	1.5
Hormone in warm water	19					
Minus Hormone in cold water	29	—8.0**	—16.6**	1.7	19.1*	1.4

* Significant to 5 per cent point ** Significant to 1 per cent point

to the inference that the differences in drop in 1941 were possibly due to factors other than spray treatment.

A carefully controlled test was made in 1940 on selected branches of two McIntosh trees. The fruit, pedicels, and spurs were thoroughly sprayed during the warmest part of the day with the same commercial product used in the previously reported test. The treatments were as follows: On September 10, at the first sign of dropping, all branches except the controls were sprayed. These branches were again sprayed on September 22, also some other branches were sprayed for the first time. The apples attached to the branches were counted immediately following spraying and on several later dates. From Table 15 it may be seen that dropping was retarded only for the first six days following the spray application of September 10. Outstanding is the variation between branches on the same tree and between different trees in response to the hormone spray. Hitchcock and Zimmerman[5], using spray made up of derivatives of naphthaleneacetic acid, also found differences in response between trees of the same variety and between branches of the same tree.

Although trees sprayed on September 10 were not further benefitted with relation to fruit dropping by a second spray application made on September 22, those branches sprayed for the first time on

Table 15. Per Cent Drops (cumulative) of McIntosh when Sprayed with Napthaleneacetic Acid

Treatment	Sprayed 9/10 and 9/22				Control not Sprayed			
Tree	241 A		251 A		241 A		251 A	
Branch	a	b	a	b	c	d	c	d
Date								
9/10	0	0	0	0	0	0	0	0
9/16	0	2	0	0	7	17	27	12
9/22	0	14	22	8	14	24	36	19
9/24	4	18	39	12	19	32	36	29
9/30	44	47	73	70	67	52	88	78

September 22 (Table 16) dropped less fruit in the succeeding eight days than the controls. In this case it is apparent that the "hormone" sprays were effective only in retarding the dropping of fruit which had not previously received a "hormone" spray. The McIntosh drop seemed generally to be retarded immediately following the spray of September 10. There was as large a percentage drop from unsprayed branches on September 16 as on sprayed branches on September 23. The effectiveness of the hormone spray then decreased rapidly so that an equal percentage of drop occurred on unsprayed branches on September 22 as on sprayed branches on September 25. Following this date equal amounts of dropping occurred on sprayed branches two days later than on unsprayed ones.

Table 16. Per Cent Drops (cumulative) of McIntosh after September 22 when Sprayed with Napthaleneacetic Acid

Treatment	Sprayed 9/10 and 9/22				Sprayed 9/22 Only				Controls not Sprayed			
Tree	241 A		251 A		241 A		251 A		241 A		251 A	
Branch	a	b	a	b	g	h	g	h	c	d	e	d
Date												
9/22	0	0	0	0	0	0	0	0	0	0	0	0
9/24	4	4	22	4	3	0	0	7	6	10	0	13
9/30	44	38	66	67	30	11	64	28	62	37	81	74

Improved knowledge concerning the date, method of application, strength and kind of hormone, and temperature of the air at the time of spraying apparently explains in part why better results have more recently been obtained in reducing pre-harvest drop of McIntosh. In 1942 and 1943, Hoffman *et. al.*[8, 9], found hormone sprays and dusts equally effective in reducing the pre-harvest drop in New York. Southwick[17, 18] found dusts less effective than spray in Massachusetts. Ellenwood and Howlett[5], in Ohio, obtained favorable results with commercial naphthaleneacetic acid on Stayman Winesap but not with Delicious or Red Rome Beauty. Although McIntosh was affected by the last spray, the fruit that remained on the tree was overmature.

Batjer and Marth[3] present data for McIntosh, Delicious, and Stayman Winesap sprayed with naphthaleneacetic acid. They state, "With this variety (McIntosh) the effective period seems to be generally 10 to 12 days with one application." An examination of the charts presented in their paper reveals that with only one hormone spray McIntosh apples were actually retarded from dropping for only two days. Since this is the time interval between dates of equal amount of fruit drop between treated and non-treated trees, this would seem to be a conflict with their statement that the spray is effective for 10 to 12 days. Rather, it seems that the statement should have been that heavy dropping began 10 days after the spray was applied. Murphy[13] also claims that the "effective" period of hormone spray persisted for 10 days, whereas the data presented indicate only that the fruit did not drop excessively for 10 days after spraying. He

did not present data to show on what dates an equal amount of dropping occurred on sprayed and unsprayed trees, which should indicate the true effective period.

Batjer[1] found that spraying with naphthaleneacetic acid with the air temperature at 82°F. and 63°F. had a differential effect on fruit drop with Delicious and Winesap and that the rate of drop was considerably less following spraying at the higher than at the lower temperature. However, equal amounts of drop at the two temperatures were not more than two to three days apart.

SUMMARY

Although heavy- and light-dropping McIntosh trees seemed more or less segregated into groups in the orchard, differences in soil profile, root distribution, or number of small roots per tree were not large enough to account for differences in drop except that small roots were more numerous in the lower levels of the soil under heavy dropping trees than under light-dropping trees.

The soil was a Charlton loam consisting of four distinct layers, or zones, and an underlying hard till layer. The A and B zones were weathered material, the C and D zones only slightly weathered. The A and C zones were universally present. The D zone contained many small and some large stones. No stones were found where the D zone was absent.

Small roots penetrated all four zones, but rarely into the till layer except where it was closest to the soil surface.

The density of population of small roots was greatest in the C and D zones under both heavy- and light-dropping trees.

There is some evidence that heavy-dropping trees were on slightly more acid soil than light-droppers.

The differences in amounts of available nitrogen, potassium, magnesium and calcium under heavy- and light-dropping trees were not sufficient to account for differences in apple drop. The phosphorus content of the soil was slightly higher under the lighter droppers.

Variation in correlation between per cent drops and yield from year to year was large. Low and moderate positive correlation coefficients were found with McIntosh in some years. With Northern Spy the correlation was most frequently negative. Significant correlations were not restricted to heavy-yield years.

Variation within seasons, individual trees, date of harvest, and undetermined factors render the correlation coefficients of per cent drop versus yield of little or no value in estimating the number of bushels of fruit dropped in a given orchard. Correlation between weight of drops and yield, and its regression equation, gave a better picture of effect of yield on drop.

Very high correlations were found between total weight of drops and yield over a period of years.

Although certain thinned trees dropped less fruit than unthinned trees, with others the reverse was true. Thus for all trees the difference in drops due to treatment was not statistically significant.

Dropping was retarded when trees were sprayed with borax.

Seed number was slightly higher in early drops than in those dropping near the date of harvest. Dropped apples had one to two fewer seeds than those picked from the tree at harvest time. Tree-picked fruits were larger than fruits that dropped just previous to harvest.

Fruits from thinned trees were larger in both dropped and picked lots than from unthinned trees. No such difference existed between borax-sprayed and unsprayed trees that were not thinned.

The early-dropping fruit apparently colored on the tree in advance of those remaining attached until harvest time.

Fruit on borax-sprayed trees averaged more red color on any given date than fruit on unsprayed trees, although differences on any given date were not statistically significant.

Variability in results when McIntosh trees were sprayed with naphthaleneacetic acid leads to the conclusion that this substance does not always delay dropping. In one test dropping of equal amounts of fruit was delayed not more than two days.

Fruit-dropping of Melba, Early McIntosh, Gravenstein, and Milton was very definitely retarded following a naphthaleneacetic acid spray.

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